sions, although we must admit that the explorers chose a cold winter to visit North Dakota. The records from the Bismarck (N. Dak.) station for comparative purposes have been furnished through the courtesy of Mr. Orris W. Roberts, official in charge of the Weather Bureau office at that station. Captain Lewis or Captain Clark read their only thermometer themselves personally at sunrise and 4 p. m. each day and entered the readings in the meteorological register.

A computation of the mean temperature from November to March, inclusive, at Bismarck from November, 1924, to March, 1929, discloses that the monthly mean temperature at that place averaged 0.7° lower than the mean of the temperature at sunrise and 4 p. m. Deducting that amount from the mean monthly temperature for the winter months of 1804–5 as shown in the Lewis and Clark record gives a fair comparison with modern Weather Bureau records at Bismarck, N. Dak.

Using a −.7° correction to the mean of the sunrise and 4 p. m. readings during the winter of 1804–5 to reduce the temperature to a monthly mean basis, Lewis and Clark would have obtained the following results at Fort Mandan: December, 1804, 3.1°; January, 1805, −3.9°; and February, 1805, 10.5°.

The records show that Lewis and Clark encountered the coldest December and January combined of record in the vicinity of Bismarck, although December, 1879, and December, 1927, were colder than in 1804; and January, 1875, 1887, 1888, and 1916 averaged lower than January, 1805. The minimum temperature at Fort Mandan for December, 1804, was −43° on the 17th, which was 1° lower than the absolute December minimum at Bismarck established on December 20, 1916. November, 1804, was 4.2° warmer than the 55-year average at Bismarck, February, 1805, 0.2° warmer, and March, 1805, 3.5° warmer.

A perusal of the interesting initial diary of the Missouri Valley does not disclose, however, that the climate 125 years ago in the home of the tornado and the blizzard differed much from what it is to-day. The original engineer of the Great Plains, the American bison, who followed the lay of the land and the run of the water, thrived in vast herds under similar climatic conditions and less protection than the horse, cow, and sheep do to-day.

Delving into old records and getting the viewpoint of past generations holds a fascination and it has amply repaid me for the reading of the Original Journals of the Lewis and Clark Expedition, printed from the original manuscript and now in the possession of the American Philosophical Society. Most of the subject matter of this paper was obtained from that source. One of the happy rewards for a person who has been studying stream flow in the Missouri River for years was the discovery of what is probably the origin of the fallacy that the annual rise in the middle and lower Missouri River, commonly known as the June rise, is due to the melting snows in the northern Rocky Mountains.

The Lewis and Clark expedition were detained about seven weeks in the northern Rockies on the return journey in consequence of the snow, and the experiences encountered lead Captain Lewis to write, on June 2, 1806: "I have no doubt but that the melting of the mountain snow in the beginning of June is what causes the annual inundation of the lower portion of the Missouri River from the first to the middle of July." This mistaken idea persists in the minds of a large percentage of the dwellers of the Missouri Valley. Its origin may have been in the statement just read, although the explorers may have been mislead by the Indians, who are in many cases not interested enough in rivers even to give them a name. As an example, the Columbia River has no name among any of the tribes living on it. The cause of high water during June and July in the middle Missouri River was shown by Charles D. Reed in his article on "Floods of the upper Missouri River," MONTHLY WEATHER REVIEW, June, 1911, to have been due to heavy rainfall, with the mountain snowfall exerting a negligible influence.

Speaking of rivers, it is worth while to recall that while Captain Lewis was descending the Ohio on the outward journey he wrote to President Jefferson, from Wheeling, W. Va., on September 8, 1803, as follows: "The River (Ohio) is lower than it has been known by the oldest settlers in this country. On many bars the water in the deepest part does not exceed 6 inches." Again, on October 3, at Cincinnati, Ohio, he remarked, "The water still continues lower in the Ohio than it was ever known."

Lewis and Clark named many rivers of the Northwest. They terminated the name of the Missouri River at Three Forks, Mont., and on July 28, 1805, the following entry appears in their diary: "Both Captain Clark and myself corresponded in opinion with the impropriety of calling either of these streams the Missouri and accordingly agreed to name them after the President of the United States and the Secretaries of Treasury and State, having previously named one river in honor of the Secretaries of War and Navy. In pursuance of this resolution we called the southwest fork, that which we meant to ascend, Jefferson River in honor of that illustrious personage, Thomas Jefferson (the author of our enterprise), the middle fork we called Madison River in honor of James Madison, and the southeast fork we called Gallatin River in honor of Albert Gallatin."

I have endeavored to set out not only weather conditions of interest as found by Lewis and Clark on their great expedition of exploration but other items of public interest as well in this new era of developing what ought to be the longest river in the world, the Missouri—a river with a romantic past and a useful future.

MUD FLOODS IN UTAH

By J. CECIL ALTER

[Weather Bureau Office, Salt Lake City, Utah]

Numerous rapid and heavy local downpours of rain during the first two weeks in August produced an extraordinary number of washing floods in the mountain sections of Utah, several of them similar to the destructive earth washes of July 10, 1930, between Centerville and Farmington.

The first of these floods, on the afternoon of August 2, flooded an area of approximately a square mile of industrial section in northwestern Salt Lake City with slime, gravel, and rocks from the steep, smooth mountain side adjacent, and from the caving walls of gravel pits and other excavations. Rivers of mud ran down the streets and roads and over a wide area of improved premises, while in the more concentrated parts of the avalanche great masses of moraine gravel and rocks were transported and deposited into depressions, more especially in the cut through which the State-paved highway passes parallel to the foot of the slope.

One flow of mud and earth from 400 to 500 feet wide and about 2,000 feet in length, left a ridge of earth 4 feet deep on the paving just north of Warm Springs. A quarter of a mile farther northwest where the paving passes for about 2,000-feet through a cut from 15 to 20 feet in depth in the ancient moraine there were three gravel washes from 300 to 500 feet wide that filled the cut from a quarter to half full. (See fig. 1.) Another huge wash crossed the open roadway near Becks Hot Springs, 1½ miles farther northwest, where basements and premises were flooded with water dammed up by the railroad grades. The total loss and repair expense resulting from this flood is estimated at $25,000.

On August 8 a rapid flow of water, mud, and rocks dashed out of a shallow gully in the face of the mountain just north of Cedar City, Iron County, depositing earth and bowlders across the State highway to depths of 1 to 3 feet, and covering an area 200 or 300 feet wide and about 1,500 feet long. A little farther north in Parowan Canyon on the same afternoon, and repeated on the 10th, the headworks of the municipal water system and some of the water lines were badly damaged by sudden rushes of water resulting from local canyon rains.

August 9th: An immense flood dashed out of Cottonwood creek, Emery County, destroying irrigation works and filling canals at Orangeville and Castle Dale; in Ophir Canyon, Tooele County, the highway and the powerhouse pipe line were considerably damaged by floods of mud and water; and at Bountiful, Davis County, water overflowed the streets, watering some basements and flooding some land in truck crops. Simultaneously the old mud flood of August 2, near Becks Hot Springs, in Salt Lake City limits, was overrun again, re-covering the State highway paving with mud, and burying the adjacent tracks of an interurban electric railroad. Also at this time another rush of water on top of the old mud flood of July 10 at the south edge of Farmington, Davis County, still in impressive evidence, refilled part of the excavation made through it on the paved highway and extended the area covered, reaching the interurban tracks which it covered to a considerable extent. At Promontory, Boxelder County, a heavy local rain on the 8th and 9th damaged railroad property and improvements, stranded several automobiles on the highway, and flooded and silted a few business and residence basements and premises.

The culmination of this series of floods began toward noon on Monday, August 11, when a heavy downpour of rain on the Oquirrh Mountains augmented the damage done at Ophir on the 9th, shot a considerable acreage of gully mud and gravel to the mouth of Mercur Canyon, and ejected a roaring torrent of water, mud, and rocks out of Carrs Fork into Markham Gulch, a branch of the narrow canyon town of Bingham, near the Salt Lake-Tooele County line, crushing or half burying about 20 Utah Copper Co. cottages and a few privately owned residences, caving in the rear wall of the company hospital rather badly, crushing an automobile and several outbuildings and fences, breaking a few telephone and electric lines, and piling rocks and slimy earth to a depth of from 1 to 15 feet for a distance of several rods in the settled part of the canyon and a considerable distance above. (See fig. 2.) The duration of this flood was about two and one-half hours. Property loss and immediate rehabilitation expense will be at least $75,000.

Before the thundering avalanche at Bingham had become silent a torrential rain set in along the west slope of the Wasatch Mountains north of Salt Lake City, which not only started several minor flows of sand and gravel, but at Centerville, Davis County, rapidly sluiced an immense island of mud into the northern edge of that village and over the adjacent fruit and truck growing areas, wrecking or rendering uninhabitable seven or eight good residences and destroying barns, outbuildings, fences, implements, tools, irrigation waterways, nursery stock, and growing or unharvested crops, and covering and damaging an area of land several hundred feet in width and a half mile in length, and almost totally destroying the value of about 50 acres of valuable land, now badly washed, and piled and littered with rocks and huge bowlders, many of them from 50 to 100 tons in size, and a few estimated to weigh as much as 150 tons each. The large Centerville public-school building was badly damaged by breaking windows, caving in the east wall, and filling up the yard in places above the main floor, while the State-paved highway was covered deeply with mud and rock for a distance of nearly a thousand feet.

Simultaneously a similar cascade of great turbulence came out of Ford Canyon, 1½ miles farther north, which deposited a tract of mud from 1 to 6 feet deep, several hundred feet wide, and about three-quarters of a mile long, covering interurban railroad tracks and necessitating detouring and portaging passengers and freight for some time, and burying the State-paved highway so badly it has been decided to erect thereon a structure several feet high and about 1,500 feet in length. Four or five dwellings were destroyed, along with their premises, outbuildings, and much property, including the crops on a large acreage of land as well as the temporary usefulness of most of the land, and the permanent usefulness of about 25 acres of crop land and orchards; and a dozen cows and more than a thousand chickens and some other livestock. In these two floods about 200 acres of crops were destroyed or badly damaged, some of the land being permanently ruined, though in use for many years past. The total immediate loss will be about $125,000.

The next day, Tuesday, August 12, moderate floods went across the state-paved highway at Springville, Utah County, damaging the State and Federal fish hatcheries somewhat; and at Ironton, near by, where some débris was deposited on the paving and in the fields. The city of Ogden was drenched with a widespread sheet of running water causing moderate damage, while another flood ran across the paving near Willard, Boxelder County, damaging some farm lands near by. A similar flood of mud occurred at Grantsville, Tooele County, where the highway was heavily covered with earth, and several cellars and ground floors were more or less mudded and wetted. A flow of muddy water ran through the town of Tooele, Tooele County; and the premises of the Arthur Mill, near Garfield, Salt Lake County, were partly overrun with mud from a local gully wash, watering and silting some boiler rooms and other subsurface floors. At Magna, near by, a considerable head of water and mud splashed through the business district, moving two dwellings from their foundations, silting several homes, and wetting and mudding the storeroom floors of several retail establishments. An estimate of the loss caused at Magna and Arthur (including a little further damage at Arthur on the 13th) is about $25,000.

Still further on August 12, several minor sand and gravel runs started by heavy rains crossed the highway in Parleys Canyon, near Salt Lake City; and at the same time the earlier mud deposits between Centerville and Farmington were again overrun with water, hindering the work of rehabilitation and making matters worse in some respects. Ophir Canyon suffered further washing injury, and the Bingham mud deposit of the 11th was again overrun resulting in some further damage and incon-

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FIGURE 1.—Automobile buried in mud flood of August 2, 1930, in highway cut at northwestern edge of Salt Lake City, Utah. The car, suddenly halted by the flood, was buried in about 30 minutes. Five passengers escaped

FIGURE 2.—Street in Markham Gulch (upper Bingham), Utah, following the mud flood of August 11, 1930

venience, while American Fork Canyon sent a flood of mud and rocks onto the adjacent grain fields and over the roadway, near Alpine, Utah County. At Mount Emmons, some fields and roads were flooded and a cow drowned; and near Moroni, Sanpete County, highways, fields, and crops suffered damage in excess of $500. The mountain highway between Richfield and Fish Lake, Sevier County, was closed by mud washes, necessitating long detours. The heaviest earth wash on this date came out of Snowslide Gulch in Provo Canyon, Utah County, just above Donnan's Upper Falls Resort, where about noon a run began which in a short time laid down a body of mud that extended entirely across the canyon and buried the highway from 1 to 8 feet deep for a distance of nearly 500 feet. Provo River was dammed up to a height of 2 feet above the railroad tracks, and a power company water flume was considerably damaged. Automobile traffic was towed through the pool of water for two weeks, though drag lines lowered the water level away from the railroad in a few days.

Other deluging rains on Wednesday, August 13, augmented the flood conditions in all the damaged areas in Davis, Salt Lake, Tooele, and Utah Counties. The interurban electric railroad near Farmington was covered with mud again, and the track was undermined by running water just north of town. The highway excavation through the Ford Creek flood was so badly refilled, the project was abandoned and a corduroy detour constructed over the débris to one side. New mud washes in Provo Canyon hampered the work of repairing the highway, and marooned several automobiles between the floods of mud. A second flood of mud ran through the premises of the Arthur ore concentrating mill near Garfield, silting the works extensively with mud, which can be removed from many places only at heavy expense. A large concrete highway bridge over Price River between Helper and Price, Carbon County, was undermined and broken down, the flood waters also breaking two water pipe lines. Silver City, Juab County, suffered from a rush of water through the village, while over toward Elberta, Utah County, heavy floods tore their way down Big Government Canyon, damaging a bridge and several miles of railroad. Three cottages were carried away at the Apex mine, and the highway and a considerable acreage of farming land were overflowed, largely with mud, near Elberta.

Though measurements of rainfall at substations in the vicinity of flooded areas appear to bear no very consistent relation to the magnitude of the various floods, it is perhaps significant that the total rainfall for the State during August was about two and one-half times the normal amount.

CLIMATIC CYCLES

By PROF. ALBERT W. GILES

[University of Arkansas, Fayetteville, Ark., August 1, 1930]

In the MONTHLY WEATHER REVIEW of December, 1929, Doctor Marvin describes a simple apparatus devised to illustrate graphically cycle recurrences with variable length of both period and amplitude. The device, which is designated an "harmonic analyzer," possesses elements which may be readily made continuously and irregularly variable during its operation, resulting in a curve representing any desired irregularity in period and amplitude of the cycles composing the sequence illustrated by the curve. An equation by Fujiwhara is cited by Doctor Marvin as the first attempt to analyze mathematically the problem of periodicities with variable length and amplitude. In concluding his article Doctor Marvin very properly advises that "we should not require one mechanical model of this kind to represent all the details of a complex periodic curve, but rather the problem is to find a comparatively few elements having individual and separate variable amplitudes and periods of their own, which in combination produce the complex curve nature gives us."

The continuous changes marking the progress of climate through the ages would seem admirably adapted to representation as a curve involving cyclical recurrences possessing variable length of both period and amplitude. But climate is a composite consisting of several elements each of which is irregularly variable, and variation in one need not and frequently does not coincide with variation in the other elements. Hence the superposition of the curves representing the histories of the several climatic elements upon a grid or other graphic base would only result in a network characterized by the absence of harmonic or mathematical precision.

Even the graphic representation of a single element of climate is difficult, particularly when the curve is extended backward to illustrate the history of that climatic element in its progress through geologic time. The difficulty, of course, may be largely overcome by considering only the contemporary history faithfully recorded instrumentally, but after all the progress of climate through the ages is an interesting and vital part of climatology, a part that may throw light upon present climatic conditions, just as the history of organisms through the ages is a part of biology and an aid to the biologist in his interpretation of biologic factors, as, for example, contemporary distribution of organisms, the origin of vestigial structures, and evolution.

The essential elements that comprise the composite called climate are temperature, pressure, wind direction and velocity, humidity, cloudiness and sunshine, amount and kind of precipitation, and types of storms. A detailed description of the climate of a locality or a region would include not only the daily, monthly, seasonal, and annual averages for each of the climatic elements, but also indicate significant daily, monthly, seasonal, and annual departures from the averages. Obviously, the more detailed the description of the climatic elements, the larger the number of climatic provinces that may be differentiated. For the United States 10 climatic provinces are recognized and described by Ward in his Climates of the United States. On the other hand, a map recently published describes the "climates" of Maryland and Delaware, representing a very refined classification. But using the refinement in classification comparable to that of Ward it is possible to recognize probably 25 or more climatic provinces in North America.

In going back into geologic time the evaluation of climatic elements becomes increasingly difficult. As a result, temperature is the element usually considered, the others being wholly neglected or their importance inadequately summarized. It is highly probable that certain elements of climate, such as humidity, average sunshine, and average cloudiness, can never be more than roughly estimated for most of the geological periods; on the other hand, it is reasonably certain that the climates of the geologic past will be eventually much more thoroughly understood in details and in duration than they now are.